

DRIVERS AND IMPACTS OF ICT ADOPTION IN THE EUROPEAN TRANSPORT AND LOGISTICS SERVICES

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ABSTRACT

The availability of high quality transport and logistics services (TLS) is of paramount importance for growth and competitiveness of the European economy. The objective of this paper is to describe, from the continuous innovation perspective, how companies in this industry use ICT for conducting business and to assess the impact of this development for firms and for the industry as a whole. Using the SCP model and the bi-directional relationships of its elements the paper identifies the links between ICT adoption and innovation dynamics. Moreover, the analysis allows identifying the driving forces of ICT and its impact on selected business dimensions. On the driver's side, there are three points that are worth mentioning: increasing market competition, the relationships of firms interacting with each other and the availability and quality of complementary assets such as employee skills and IT know-how. On the impacts' side, firms advanced in terms of ICT usage are more likely to have outsourced business activities. Finally, a set of recommendations on how to further improve the continuous innovation factors in the TLS industry is presented.

Keywords: ICT, e-business, transport, logistics, innovation.

1. INTRODUCTION

Transport and logistics services (TLS) are key components of a successful economy, enabling the movement of goods, services and people as efficiently as possible. In the European Union, the transport sector generates 7% of European Union gross domestic product (GDP) and for around 5% of employment. Nevertheless, the challenge is to find solutions for freight and passengers that are economically viable and that also promote sustainable growth, fuel economy, the reduction of emissions, safe and healthy lifestyles and social inclusion.

Road transport services account for 1.6% of the EU GDP and give jobs to 4.3 million people. The whole economy and society depends heavily on efficient road transport: 44% of the goods are moved by trucks (compared with 41% for short sea shipping, 10% for rail and 4% for inland waterways) and 85% of the persons are moved by cars, buses or coaches (compared with 5% by air and 6% by railways) (European Commission, 2007). Logistics is the process of planning, implementing and controlling the movement of people, raw materials, half-finished products and finished goods. These should arrive in time at the right destination and retain the right quantities and quality, while respecting the level of service selected for the process. The global logistics industry is estimated at 13.8% of the global EU GDP.

To obtain the quality solutions needed in the organisation and operation of the European transport and logistics services, the use of interoperable information and communication technologies (ICT) should be encouraged further as a matter of priority. Technological trends will meet the demand for comfort, safety and speed through advances in ICT and telematics (traffic and transport management systems, travel information and reservation systems, vehicle guidance systems, mobility cards). Using e-business technologies, the TLS companies can improve their productivity, create an integrated approach linking transport modes in innovative ways and, thus, improve the quality of their services.

The objective of this paper is to describe how European companies in the TLS industry use ICT for conducting business and to assess the impact of this development for firms and for the industry as a whole. The analysis presented is based on a survey financed by the European Commission through the e-Business W@tch Programme. The survey was carried out during 2007 in seven European countries (France, Germany, Italy, Poland, Spain, Sweden and United Kingdom) and covers the following business activities: land/road and rail transport (NACE Rev. 2, 49.1, 49.2, 49.3, and 49.4) and logistics sectors of warehousing and storage, cargo handling and other transportation support activities (NACE Rev. 2, 52.10, 52.24, and 52.29) to the extent that these sectors interact with transport activities.

The analysis is presented in three parts. Firstly, it is brought a descriptive assessment focused on the ICT existing infrastructure, the diffusion of ICT-based applications, and on how they are used by companies in the TLS industry. The second part provides a complementary analytical perspective on the drivers and impact of ICT adoption, based on statistical analysis. This analysis is based on a set of hypotheses, which focus on the critical role of ICT for innovation in this industry in one specific dimension: innovation dynamics. Finally, we present the conclusions and recommendations on how to improve the actual scenario of e-business in the TLS industry in Europe.

2. THE ROLE OF ICT IN TRANSPORT AND LOGISTIC INDUSTRY

Transport firms need to manage information effectively and to integrate several activities including inbound and outbound transportation, distribution, warehousing, and fleet management, in order to streamline the physical product flows of their customers. The ICT are important to logistics, since they make available the right information, at the right time and at the right place. This popular logistical paradigm, which most often refers to physical goods, is shown to have equal relevance in the management of information (Introna, 1991).

On the path to the adoption of e-business, connectivity is the first step and also a precondition for all potential benefits of the use of computer networks. The tendency of the firms in the sectors is to have a higher broadband connection. Only 17% of the companies (representing 8% of the sectors workforce) still use an Internet access up to 144 kbit/s, while a half of the firms have bandwidth connection ranging from 144 kbit/s to 2 Mbit/s and near a third have more than 2 Mbit/s bandwidth connections.

The adoption of internal computer networks is a critical step towards the computer integration of business processes. In the TLS industry a half of all firms (75% for the logistics) representing 75% of employees operate a LAN. However, the deployment of WLAN technology only reach 22% of the firms, although it is already used by about a

half of the large-sized firms, and even one third of the small companies (Table 1). The size and scalability of any computer network are determined both by the physical medium of communication and by the software controlling the communication (i.e. the protocols). Around one quarter of the TLS firms uses an Intranet and, again, it depends on the company size, ranging from a relative small 23% for micro-sized firms to a high 77% for large firms. Only a few firms in the industry use an Extranet (6%), most been used by large-sized firms (42%).

ICT	LAN		WLAN		Intranet		Extranet	
Weighting	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %
Sectors	75	50	39	22	52	24	24	6
Passenger trans.		43		22		17		5
Freight transport		44		20		25		5
Logistics		75		27		30		7
Size								
Micro		48		20		23		5
Small		62		33		26		9
Medium		87		43		55		23
Large		95		52		77		42

Table 1. Networks and protocols used in the TLS industry

ICT systems are critical for managing logistics operations. The characteristics of the TLS industry have determined the introduction of specific ICT technologies accordingly to sectors operations. However, some conclusions could be made from the presented data: one tenth of the TLS firms use a fleet control system, the rate of adoption depending again on firm's size. The less used technologies are the intermodal transportation management system (4%), a cargo handling technology (5%) and an Intelligent Transport System (7%). More advanced systems, for example for cargo handling and fleet control, are mostly used by mid-sized and large companies in the freight transport and logistics sectors (Table 2).

ICT	Maintenance management system		Cargo handling technology		Fleet control system		Intermodal transportation management system		ITS	
Weighting	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %	Empl. %	Firms %
Sectors	32	15	16	5	29	10	12	4	16	7
Passenger trans.	29	18	3	0	24	3	1	0	10	2
Freight transport	32	13	18	4	26	9	10	6	18	10
Logistics	28	20	24	8	39	17	24	2	17	1
Size										
Micro		14		3		8		4		6
Small		23		12		22		6		8
Medium		34		20		35		10		14
Large		47		31		43		21		25

Table 2. Use of specific ICT solutions for TLS industry

3. DRIVERS AND IMPACTS OF ICT ADOPTION

This section focuses on the economic impact of ICT in the TLS industry, in particular by analysing links between ICT adoption and innovation dynamics. Economic literature suggests that the ongoing diffusion of ICT and e-business technologies among firms in the economy at large is a striking example of the possible dynamics of technological change and economic development (Breshnahan and Trajtenberg, 1995; Helpman, 1998a, 1998b).

The adoption and diffusion of new technologies can be spurred by many different drivers and can have far-reaching consequences. For this study, an extended Structure-Conduct-Performance (SCP) paradigm was used as a conceptual framework for the analysis of ICT impacts (Mason, 1939; Bain, 1951). The term structure is used here meaning industry structure, which includes but goes beyond market structure characteristics of the original concept. These industry structure components influence a firm's conduct. The conduct aspects most important here are production strategies, particularly with regard to inter-firm collaboration, as well as investments in ICT and in ICT-enabled innovation. Finally, a firm's performance is assumed to be the outcome of its conduct. Successful innovations improve firm performance by, for example, reducing production cost, increasing productivity, improving product quality or enabling it to enter new markets. This may eventually lead to increased sales, turnover and market shares.

In contrast to the standard SCP paradigm, the flow of causality is in fact not one-directional (Fauchart and Keilbach, 2002; Nepelski, 2003). It is assumed that firm performance may have a feedback effect on both firm conduct and industry structure, and conduct may have a feedback on structure. This conceptualisation allows for an enhanced economic approach that studies the drivers and impacts of ICT and ICT-enabled innovations at the firm and sector level. Figure 1 illustrates the SCP model and the bi-directional relationships of its elements.

In the following discussion we explore links between ICT adoption and ICT-enabled innovation. The analysis proposes a set of four hypotheses based on a literature review and considering the data from the study.

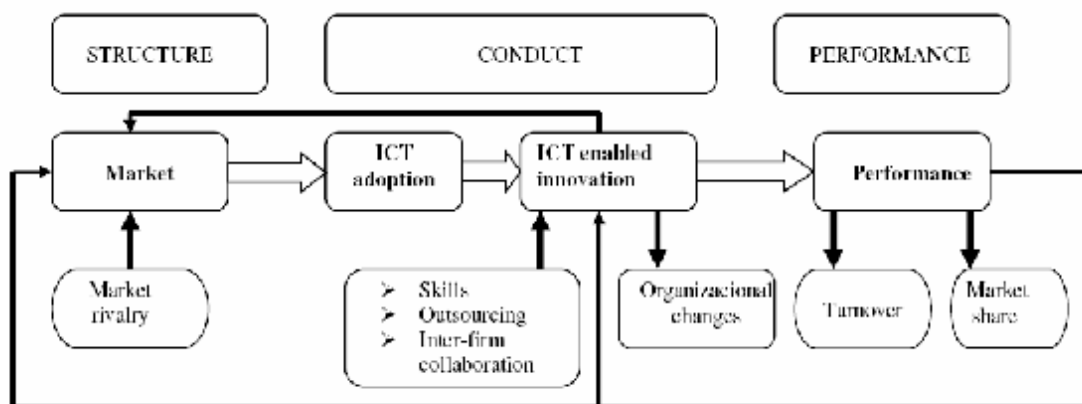


Figure 1. Conceptual framework for the analysis of drivers and impact of ICT adoption

3.1 ICT AND INNOVATION DYNAMICS

The growing diffusion of ICT in all areas of business is a major enabler of technological change, innovation and thus economic development. ICT-driven innovation activity is central to the subsequent effects of ICT economic impact. As a general purpose, ICT can have significant effects for downstream innovation in several sectors. For example, service innovation in the logistics industry can enable manufacturers to improve their customer service.

This analysis offers further insights to what degree specific factors are linked with ICT-enabled innovation in the TLS industry and whether companies which conduct ICT-enabled innovation are likely to exhibit superior performance.

Internal capacity

Knowledge stock and skills found a firm's absorptive capacity to adopt new technologies (Cohen and Levinthal, 1989). This, in turn, has positive impact on a firm's innovation performance. Thus, in order to develop marketable products or feasible production processes a firm needs to build up its knowledge stock and expertise, i.e. complementary assets. The most obvious example of investments in complementary assets include investments in software, training and organisational transformations that accompany ICT investments. In other words, firms that combine high levels of ICT and high levels of worker skills have better firm innovation performance. Thus, the following hypothesis can be formulated:

Hypothesis 1: *Firms characterised by a higher share of employees with a university degree are more likely to conduct ICT-enabled innovations, in comparison with their peer-group in the same sector.*

In order to focus the analysis only on ICT-enabled innovations, a dummy variable was constructed out of companies' answers to the questions on whether their product or service innovations introduced by a company in the last 12 months were directly related or enabled by information or communication technology. It takes a value of "1" if any product or process innovations were directly related to or enabled by ICT and "0" otherwise. The main explanatory variable is the share of employees with a higher university degree.

To additionally account for the effect of internal capacity on innovation, a variable controlling for the presence of ICT practitioners was added. This should control for the effect of ICT-specific skills on a company's innovative potential. Furthermore, the model includes also variables controlling for firm size and country of origin. Except for the variable on the share of educated employees, all independent variables are dummy variables, taking a value of "1" if a specific characteristic is identified, and "0" otherwise. To analyse the relationship between ICT-enabled innovation and the share of employees with a university degree, a probit regression was run.

Table 3 shows the results of the regression. An analysis of the results leads to the following conclusions: changes in share of employees with a higher university degree positively affect the likelihood of conducting ICT-enabled innovations. Similarly, employing IT practitioners significantly increases firm's propensity to use ICT to

develop new products and services. This finding provides further evidence that the success of the ICT-driven innovative process depends on the availability and quality of complementary assets.

Independent variable	Coefficient	Standard Error
% of employees with higher university degree	0.005*	0.002
IT practitioners	0.920**	0.117
Less than 249 employees	-0.014	0.230
Model diagnostics		
N = 845; R-squared = 0.09		
Note: Probit estimates. The table does not report the country coefficients.		
* Significance 95%, ** Significance 99%		

Table 3. Effect of employee skills on ICT-enabled innovation for the TLS industry

ICT deployment and outsourcing

Following transaction cost theory, decreasing costs of search, evaluation and monitoring of suppliers should lead to a shift away from firms and toward markets as a form of organising economic activity (Coase 1937, Williamson, 1985). Consequently, the expectations regarding the potential of ICT as technologies introducing innovative ways of doing business, re-shaping firm boundaries and changing the constellations of value chains were enormous (Johnston & Lawrence, 1988; Milgrom & Roberts, 1990; Fulk et al, 1995). The availability of powerful and cheap ICT was said to increase the attractiveness of markets (Malone et al, 1987; Lucking-Reiley et al, 2001). The authors of the move to the market paradigm argued that companies would reduce their dependency on hierarchy and outsource business activities. The following hypothesis is formulated:

Hypothesis 2: *ICT endowment is positively correlated with outsourcing.*

The dependent variable can take a value “1” if a company outsourced any of its business activities in the last 12 months, or “0” if it did not. The explanatory variable controlling for a company’s ICT endowment level is an index composed of answers to the questions regarding the internet connection type (score between 1 and 4), the use of LAN, WLAN, WWW, Intranet, Extranet, ERM, SCM, CRM, the use of the internet to sell and buy goods and employing IT practitioners (one score for each positive answer). Thus, the variable can take values between “0” and “14”. In addition, the regression includes dummy variables controlling for firm size and country of origin. To analyse the relationship between outsourcing and ICT endowment, a probit regression was run.

Table 4 reports the results of the regression. An analysis of the results leads to the following conclusion: the ICT intensity increases the propensity to outsource business activities. The more advanced a company is in terms of ICT use, the more likely it is to have outsourced some business activities in the last 12 months. This provides support to the hypothesis that ICT enables companies to redefine their make-or-buy decisions and to outsource business activities that were previously done in-house.

Independent variable	Coefficient	Standard Error
ICT endowment	0.059*	0.017
Less than 249 employees	0.050	0.237
Model diagnostics		
N = 932		
R-squared = 0.051		
Note: Probit estimates. The table does not report the country coefficients.		
* Significance 99%		

Table 4. Effect of intensity of ICT use and outsourcing for the TLS industry

Inter-firm collaboration

ICT has a direct impact on process innovation in an organisational setting by facilitating inter-organisational links (Lee, 2000). ICT-enabled inter-organisational integration and collaboration enhance the innovation capabilities of companies by providing opportunities for shared learning, transfer of technical knowledge and resource exchange. The most obvious benefit of information integration with the help of ICT is the optimisation of the value chain that eliminates the bullwhip effect. Other, less obvious consequences for firms' innovativeness include creating communication infrastructures facilitating production networks or enabling partners to align the incentives of multiple players by creating joint business units or teams managing the same tasks (McAfee, 2006).

Rather than e-commerce, it is the use of electronic networks that leads to a higher probability of firms collaborating in innovative activities and increases the amount of collaborative relations they have (European Commission, 2004). The use of e-collaboration tools (such as SCM or other applications to share information about inventory levels with business partners) is critical to share data with business partners. This leads to the following hypothesis:

Hypothesis 3: *Firms that use ICT applications to exchange information or collaborate with business partners are more likely to introduce ICT enabled innovations, compared with their peer-group in the same sector.*

Again, the analysis focuses only on ICT-enabled innovations. Independent variables control is related to the use of SCM systems and sharing information on inventory levels or production plans electronically with business partners. The regression includes also variables controlling for firm size and country of origin. All independent variables are dummy variables, taking a value of "1" if a specific characteristic is identified, and "0" otherwise. To analyse the relationship between ICT-enabled innovation and the use of electronic data and information exchange between business partners, a probit regression was run.

Table 5 reports the results of the regression. An analysis of the results leads to the following conclusions: the use of applications and practices supporting the electronic exchange of information between companies (e-Collaboration tools) positively affect the likelihood of conducting ICT-enabled innovations.

Independent variable	Coefficient	Standard Error
Use of SCM	0.704*	0.139
Share information	0.599**	0.122
Less than 249 employees	-0.183	0.185
Model diagnostics		
N = 932; R-squared = 0.09		
Note: Probit estimates. The table does not report the country coefficients.		
* Significance 95%, ** Significance 99%		

Table 5. Effect of electronic collaboration with business partners on ICT-enabled innovation activity for the TLS industry

ICT diffusion and organisational change

ICT diffusion may impact on a company's organisation, i.e. the structure and the relationships between departments within an enterprise. Organisational changes may relate to a rearrangement of functions, workflows and importance of departments and employees working in them. ICT transformed the process of replicating business innovations across organisations (Brynjolfsson et al, 2006). Traditionally, deploying business innovation on a larger scale took time and required considerable involvement of resources and employees. Today, ICT allows companies to embed business innovations and then implement them across the organisation at a much smaller cost than before without compromising on quality.

The copy-exactly strategy is particularly beneficial if the initial understanding of the process is low, the lifecycle is short and the process is difficult to improve. This is true for manufacturing industries with rapidly changing production technologies and intensive technological competition. In such industries the speed of adoption of new production processes plays a decisive role for remaining at the cutting edge. On the other hand, tools, such as email, knowledge management systems, wikis or instant messaging, considerably improve the process of innovation in knowledge-intensive and service-oriented sectors with informal, unstructured and spontaneous type of work, such as banking (McAfee, 2006). ICT facilitates firms' innovativeness by propagating innovations that are less structured than business processes. This leads to the following hypothesis:

Hypothesis 4: *ICT use is positively correlated with organisational changes.*

The dependent variable controlling for organisational changes is based on companies' answers to the questions of whether they introduced changes in corporate strategy, management techniques, organisational structure and marketing concepts. For each positive answer a firm scores one point. Consequently, the dependent variable takes a value between "0", if a company did not carry out any of the listed changes, and "4" if it undertook all of them. In order to account for various effects of different ICT components on organisations, explanatory variables include:

- *Infrastructure endowment index* that comprises of hardware components used by a firm and includes the share of employees with an internet access at their workplace, internet connection capacity and the use of LAN, Intranet and Extranet.

- *Software endowment index* that comprises of software applications used by a firm. The index includes the following applications: a software application to manage the placing or receipt of orders, ERM, SCM, CRM and the use of the internet to buy and sell goods.
- *ICT human capital variable* that controls for the presence of ICT practitioners.

In addition, the regression includes dummy variables controlling for the percentage of employees with a higher university degree, firm size and country of origin. To analyse the relationship between ICT-enabled innovation and the use of electronic data and information exchange between business partners, an ordered logit regression was run.

Table 6 reports the results of the regression. An analysis of the results leads to the following conclusions:

- ICT hardware has little importance for organisational change. Hardware endowment, measured in terms of network infrastructure usage and internet access, does not increase the likelihood of introducing organisational changes.
- Software use and IT practitioners drive organisational changes. The intensity of ICT applications use and in particular IT-skilled employees are the major drivers of organisational changes. This together with the previous result indicates that ICT skills, software and hardware have different implications for companies' conduct and performance. Whereas hardware is a necessary condition for an efficient ICT use, it is not a sufficient condition for business transformation. These are rather human skills combined with innovative software that enable firms to rearrange their operations, functions and workflows, i.e. find innovative ways of doing business. Hardware infrastructure, in contrast, is already a commodity that does not offer companies any potential to create a competitive advantage.

Independent variable	Coefficient	Standard Error
Infrastructure index	0.000	0.002
Software index	0.362*	0.060
IT practitioners	0.571*	0.195
% of employees with higher university degree	0.003	0.004
Less than 249 employees	-0.312	0.338
Model diagnostics		
N = 651; R-squared = 0.05		
Note: Ordered logit estimates. The table does not report the country coefficients.		
* Significance 99%		

Table 6. Effect of ICT use and organizational change for the TLS industry

4. CONCLUSIONS

Innovative companies understand that individual or special programs such as continuous improvement, brainstorming sessions or creativity training do not make the organization innovative. Rather, the collection or portfolio of these initiatives, wrapped within a well supported climate of innovation, results in an organization loaded with skilled and passionate people who strive to make innovation a part of their daily mind set.

Due to the high turnover and number of jobs in the European TLS industry and its interrelation with almost all other European economy sectors, any improvements to the competitiveness and effectiveness of European transport and logistics enterprises will have a positive impact on other industries and, undoubtedly, will also have an impact on the European economy as a whole. Over the last few years firms operating in the TLS sector have made significant progress in their continuous adoption of new technologies, particularly those linked to ICT and e-business. ICT and e-business activities deployment has thus become increasingly important for the TLS industry and actually about 75% of companies use e-business in one way or another to realise their business activity.

The analysis allows identifying the factors that characterise the continuous innovation in the European TLS industry: the driving forces of ICT and its impact on selected business dimensions. On the driver's side, there are three points that are worth mentioning. First, increasing market competition is one of the driving forces behind ICT usage. In other words, more intense competition make companies use innovative technologies in order to cut costs and look for more innovative ways of conducting business. Second, the relationships of companies interacting with each other play an important role in the diffusion of ICT applications supporting inter-firm collaboration. Close relationships facilitate investments in specific technologies. Third, the success of the ICT-driven innovative process depends on the availability and quality of complementary assets such as employee skills and IT know-how.

On the impact's side, companies advanced in terms of ICT usage are more likely to have outsourced business activities. This provides support to the hypothesis that ICT enables firms to redefine their make-or-buy decisions. However, a detailed analysis shows that the intensity of ICT applications use and IT-skilled employees that are the major drivers of organisational changes. Hardware infrastructure, in contrast, is already a commodity that does not offer companies any potential to create a competitive advantage.

On the basis of evidence from this study, the following issues have been identified as particularly relevant for improving continuous innovation from the policy making perspective:

Improving ICT skills and managerial understanding and skills for e-business. ICT usage and high levels of employee's skills complement each other, leading to skill-biased technological change and an advantage for TLS firms with highly skilled employees in adopting and using ICT. The picture that emerges from the survey is that ICT skills are a decisive issue, especially among SMEs, notably at the managerial level, i.e. how to use e-business to support a company's strategy. Training programmes need to be more focused on managerial understanding and skills for e-business, such as how to effectively integrate e-business processes into existing business models and strategies to change organisational structures.

Promoting efforts towards innovation. The implementation of new ICT and complementary investments can lead to innovations, and innovations are positively associated with turnover growth. In other words, innovative firms are more likely to grow. The empirical evidence presented in this study corresponds with the theoretical predictions that suggest that ICT and innovation are positively associated with turnover

at the firm level. Policy makers should envisage the creation of lead programmes in fields of excellence such as logistics and transport.

Developing standards for e-business and facilitating the process of interoperability. The importance of standards as a means of reducing transaction cost and increasing competitiveness has been identified as an important barrier to e-business diffusion. Policy measures should allow for temporal and business considerations in a competitive marketplace and may include, as appropriate, active dialogue with industry on challenges in formation of value networks and other potential barriers to implementation of interoperability as well as maintaining an agenda of priority identification, target-setting and monitored progress of interoperability in respect of an evolving priority list of functional digital enablers of ICT innovation and uptake.

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